10008 JC20 Rec'd PCT/PTO 18 MAR 2002

FORM PTO-1390 (REV. 5-93) U S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	ATTORNEY'S DOCKET NUMBER 10191/2211
TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371	U.S. APPLICATION NO. (If known, see 37 CFR 1.5) 10/088218

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE(S) CLAIMED
PCT/DE00/03020	(02 09 00) 02 September 2000	(17.09.99) 17 September 1999

TITLE OF INVENTION
METHOD OF TRANSMITTING WIRELESS SIGNALS AND TRANSMITTER FOR TRANSMITTING WIRELESS SIGNALS

APPLICANT(S) FOR DO/EO/US

SCHRADER, Marc; HENTATI, Nabil

Applicant(s) herewith submit to the United States Designated/Elected Office (DO/EO/US) the following items and other information

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)) immediately rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C 371(b) and PCT Articles 22 and 39(1)
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C 371(c)(2))
   a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☒ has been transmitted by the International Bureau
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US)
6. ☒ A translation of the International Application into English (35 U S C 371(c)(2)).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau)
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☒ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U S.C 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C 371(c)(4)) (unsigned).
10. ☒ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U S C 371(c)(5)).

Items 11. to 16. below concern other document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1 98
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A **FIRST** preliminary amendment.
    ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment
14. ☒ A substitute specification and a marked-up version of the substitute specification.
15. ☐ A change of power of attorney and/or address letter.
16. ☒ Other items or information: International Search Report (translated), International Preliminary Examination Report (translated) and Form PCT/RO/101.

Express Mail No. EL594613286

JC13 Rec'd PCT/PTO 18 MAR 2002

U.S. APPLICATION NO if known, see 37 C.F.R.1.5 10/088218	INTERNATIONAL APPLICATION NO PCT/DE00/03020	ATTORNEY'S DOCKET NUMBER 10191/2211

17. ☒ The following fees are submitted:

	CALCULATIONS	PTO USE ONLY
Basic National Fee (37 CFR 1.492(a)(1)-(5)): Search Report has been prepared by the EPO or JPO .... $890.00 International preliminary examination fee paid to USPTO (37 CFR 1.482) ... $710.00 No international preliminary examination fee paid to USPTO (37 CFR 1 482) but international search fee paid to USPTO (37 CFR 1 445(a)(2)) .... $740.00 Neither international preliminary examination fee (37 CFR 1 482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO ...... $1,040 00 International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) $100 00		
ENTER APPROPRIATE BASIC FEE AMOUNT =	$ 890	
Surcharge of $130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1 492(e)).	$	

Claims	Number Filed	Number Extra	Rate		
Total Claims	12 - 20 =	0	X $18 00	$ 0	
Independent Claims	2 - 3 =	0	X $84 00	$ 0	
Multiple dependent claim(s) (if applicable)			+ $280 00	$ 0	

TOTAL OF ABOVE CALCULATIONS =	$ 890	
Reduction by 1/2 for filing by small entity, if applicable Verified Small Entity statement must also be filed. (Note 37 CFR 1 9, 1 27, 1 28)	$	
SUBTOTAL =	$ 890	
Processing fee of $130 00 for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)). +	$	
TOTAL NATIONAL FEE =	$ 890	
Fee for recording the enclosed assignment (37 CFR 1.21(h)) The assignment must be accompanied by an appropriate cover sheet (37 CFR 3 28, 3 31) $40 00 per property +	$	
TOTAL FEES ENCLOSED =	$ 890	
	Amount to be: refunded	$
	charged	$

a. ☐ A check in the amount of $________ to cover the above fees is enclosed

b. ☒ Please charge my Deposit Account No 11-0600 ~~in the~~ amount of $890 00 to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No 11-0600. A duplicate copy of this sheet is enclosed

NOTE: Where an appropriate time limit under 37 CFR 1 494 or 1 495 has not been met, a petition to revive (37 CFR 1 137(a) or (b)) must be filed and granted to restore the application to pending status

SEND ALL CORRESPONDENCE TO.

Richard Mayer

SIGNATURE

By Reg. No. 33,865 (Aaron C. Deditch)

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NAME

3/18/2002

DATE

CUSTOMER NO. 26646

439296

10/088218
JC13 Rec'd PCT/PTO 18 MAR 2002

[10191/2211]

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant(s)	:	Marc SCHRADER et al.
Serial No.	:	To Be Assigned
Filed	:	Herewith
For	:	METHOD OF TRANSMITTING WIRELESS SIGNALS AND TRANSMITTER FOR TRANSMITTING WIRELESS SIGNALS
Art Unit	:	To Be Assigned
Examiner	:	To Be Assigned

U.S. Patent and Trademark Office
Assistant Commissioner
for Patents
Washington, D.C. 20231

PRELIMINARY AMENDMENT AND
37 C.F.R. § 1.125 SUBSTITUTE SPECIFICATION STATEMENT

SIR:

Please amend without prejudice the above-identified application before examination, as set forth below.

IN THE SPECIFICATION AND ABSTRACT:

In accordance with 37 C.F.R. § 1.121(b)(3), a Substitute Specification (including the Abstract, but without claims) accompanies this response. It is respectfully requested that the Substitute Specification (including Abstract) be entered to replace the Specification of record.

The Substitute Specification reflects the text of Revised Pages 1, 2 and 2a associated with the International Preliminary Examination Report.

IN THE CLAIMS:

Without prejudice, please cancel original claims 1 to 12 and new/substitute claims 1 to 12, and please add new claims 13 to 24 as follows:

--13. (New) A method for transmitting a wireless signal using orthogonal frequency division multiplexing, the method comprising:

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modulating the wireless signal using digital phase modulation;

scanning the wireless signal after modulation to generate a plurality of scanned values of the modulated wireless signal;

determining at least one amplitude value of the wireless signal using the plurality of scanned values;

comparing the at least one amplitude value to a predefined threshold to obtain a correction signal;

determining a phase of the wireless signal;

providing the correction signal with the phase of the wireless signal;

subtracting the correction signal from the wireless signal after providing the correction signal with the phase of the wireless signal to reduce ones of the at least one amplitude value of the wireless signal that lie above the predefined threshold to a value of the threshold;

pre-equalizing the corrected wireless signal;

converting the pre-equalized wireless signal into an analog wireless signal using at least one digital-analog converter;

amplifying the analog wireless signal; and

transmitting the amplified wireless signal.

14. (New) The method of claim 13, wherein the correction signal is subtracted from the wireless signal a plurality of times, the correction signal being re-determined for each subtraction.

15. (New) The method of claim 14, wherein the correction signal includes Gauss pulses.

16. (New) The method of claim 14, wherein the correction signal is subtracted from the wireless signal, until ones of the at least one amplitude of the corrected wireless signal are at most equal to the predefined threshold.

17. (New) The method of claim 14, wherein a number of times the correction signal is to be subtracted from the wireless signal is predefined.

18. (New) The method of claim 16, wherein the wireless signal is overscanned.

19. (New) A transmitter for transmitting a digital signal, the transmitter comprising:

a modulator to perform orthogonal frequency division multiplexing (OFDM) and a phase modulation on a digital signal to be transmitted to form a modulated OFDM signal;

a processor to scan the modulated OFDM signal to generate a plurality of scanned values, determine at least one amplitude value of the modulated OFDM signal, compare the at least one amplitude value of the modulated OFDM signal to a predefined threshold to form a correction signal, determine a phase of the scanned modulated OFDM signal, provide the correction signal with the phase of the modulated OFDM signal, and subtract the correction signal from the modulated OFDM signal after providing the correction signal with the phase of the modulated OFDM signal to reduce ones of the at least one amplitude value of the modulated OFDM signal that lie above the predefined threshold to a value of the threshold;

a pre-equalizer to pre-equalize the modulated OFDM signal after the correction signal is subtracted from the modulated OFDM signal; and

at least one digital/analog converter to convert the modulated OFDM signal into an analog signal.

20. (New) The transmitter of claim 19, wherein the processor is operable to subtract the correction signal from the modulated OFDM signal a plurality of times and to re-determine the correction signal for each subtraction.

21. (New) The transmitter of claim 20, wherein the processor is operable to subtract the correction signal, until ones of the at least one amplitude of the corrected modulated OFDM signal are at most equal to the predefined threshold.

22. (New) The transmitter of claim 20, wherein the processor is operable to subtract the correction signal from the wireless signal a number of times indicated by a predefined value.

23. (New) The transmitter of claim 21, wherein the processor is operable to generate the correction signal, and the correction signal includes Gauss pulses.

24. (New) The transmitter of claim 23 wherein the processor is operable to perform overscanning on the modulated OFDM signal.--.

Remarks

This Preliminary Amendment cancels without prejudice original claims 1 to 12 and new/substitute claims 1 to 12 in the underlying PCT Application No. PCT/DE00/03020, and adds without prejudice new claims 13 to 24. The new claims conform the claims to U.S. Patent and Trademark Office rules and do not add new matter to the application.

In accordance with 37 C.F.R. § 1.121(b)(3), the Substitute Specification (including the Abstract, but without the claims) contains no new matter. The amendments reflected in the Substitute Specification (including Abstract) are to conform the Specification and Abstract to U.S. Patent and Trademark Office rules or to correct informalities. As required by 37 C.F.R. § 1.121(b)(3)(iii) and § 1.125(b)(2), a Marked Up Version Of The Substitute Specification comparing the Specification of record and the Substitute Specification also accompanies this Preliminary Amendment. In the Marked Up Version, underlining indicates added text and bracketing indicated deleted text. Approval and entry of the Substitute Specification (including Abstract) is respectfully requested.

The underlying PCT Application No. PCT/DE00/03020 includes an International Search Report, dated April 20, 2001. The Search Report includes a list of documents that were uncovered in the underlying PCT Application. A copy of the Search Report accompanies this Preliminary Amendment.

The underlying PCT application also includes an International Preliminary Examination Report, dated November 1, 2001, and an annex (including Revised Pages 1, 2 and 2a and Substitute Claims 1 to 12). An English translation of the International Preliminary Examination Report and the annex accompanies this Preliminary Amendment.

Applicants assert that the subject matter of the present application is new, non-obvious, and useful. Prompt consideration and allowance of the application are respectfully requested.

Respectfully Submitted,
KENYON & KENYON

Dated: 3/18/2002

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439582

Substitute Specification

METHOD OF TRANSMITTING WIRELESS SIGNALS AND TRANSMITTER FOR TRANSMITTING WIRELESS SIGNALS

FIELD OF THE INVENTION

The present invention relates to a method for transmitting wireless signals and a transmitter for transmitting wireless signals, respectively.

BACKGROUND INFORMATION

M. Lampe and H. Rohling: "Aufwandsgünstige Verfahren zur Reduktion der Außerbandstrahlung in OFDM-Funkübertragungssystemen" [Cost-Effective Method for Reduction of the Out-Of-Band Radiation in OFDM Wireless Transmission Systems], a lecture given at the OFDM technical conference in Braunschweig on 09/03/89, printed in the proceedings of the conference, refers to a transmitter for transmitting OFDM (orthogonal frequency division multiplexing) signals, in which a reduction of the amplitude variance reduces out-of-band radiation caused by the nonlinearity of the transmitter, by subtracting an additive correction signal from the OFDM signal to be transmitted. The correction signal is the difference between a predefined threshold and the amplitude values of the OFDM signal that lie above the threshold. If the amplitude of the OFDM signal is less than the threshold at a specific instant, then the amplitude of the correction signal at the specific instant is zero.

A method for correction of the amplitude variance is discussed in European Published Patent Application No. 735 731, in which generated partial signals are added with different signs, depending on amplitude statistics. In this manner, intervention in the coding is achieved. The additional information should be transmitted to the receiver, where it should be decoded. European Published Patent Application No.

743 768 discusses an envelope of a signal, which comprises many different signals, each modulated with frequency shift keying, being reduced by phase shift of these individual signals.

SUMMARY OF THE INVENTION

It is believed that an exemplary method and transmitter according to the present invention have an advantage in that the phase of the OFDM signal to be corrected is also impressed onto the correction signal, so that a bit error rate of the OFDM signal and thus the signal quality improve. In this manner, an expensive transmitter for OFDM signals may be modulated and utilized better.

Furthermore, a less expensive transmitter may be used for a predefined transmitter power, since the amplifier of the transmitter is utilized better.

The correction signal may be repeatedly determined and subtracted from the already corrected signal. In this manner, the influence of the correction signal on the OFDM signal may be minimized. Through such iteration, other signal components, which are enhanced by the correction signal, may be reduced again.

Furthermore, the correction signal may be composed of Gauss pulses. Gauss pulses have the same shape in both the time and frequency domains, and propagation of a Gauss pulse in the time domain results in propagation of a Gauss pulse in the frequency domain. In this manner, the handling and composition of the correction signal may be simplified.

In addition, the correction signal may be iteratively determined repeatedly and subtracted from the OFDM signal, until the OFDM signal no longer exceeds a predefined threshold. In this manner, an iterative method may prepare the OFDM signal optimally for a given amplifier of the transmitter

to optimally utilize the dynamics of the amplifier, without out-of-band radiation occurring.

Alternatively, according to an exemplary method of the present invention, how long the correction signal is determined and subtracted from the OFDM signal may be preset with experimental values. This refinement may simplify iteration of the correction of the OFDM signal.

Furthermore, overscanning may be performed on the OFDM signal before the correction is performed. In this manner, the amplitudes occurring in the OFDM signal may be established, since overscanning provides a more exact resolution of the OFDM signal to be corrected.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a transmitter for transmitting OFDM signals.

Figure 2 is a block diagram of the steps of an exemplary method according to the present invention for reducing the amplitude variance in OFDM signals.

Figure 3 is a block diagram of the steps of an exemplary method according to the present invention for correcting the OFDM signals in a processor.

DETAILED DESCRIPTION

Orthogonal frequency division multiplexing (OFDM) is a method used for mobile wireless applications. In OFDM, the signals to be transmitted are distributed to many sub-carriers, these sub-carriers having a specific frequency interval relative to one another, so that the signals distributed to the sub-carriers do not mutually interfere. This behavior is described as orthogonal.

OFDM is therefore used for digital broadcast transmission methods. These include DAB (Digital Audio Broadcasting), DVB

(Digital Video Broadcasting), and DRM (Digital Wireless Mondial). These broadcast transmission methods benefit from OFDM because only a small part of the broadcast signal transmitted is interfered with when a frequency-selective damping occurs, since the broadcast signal is distributed in multiple frequencies, and only one part of the signal is interfered with, which is transmitted on a frequency at which a strong damping occurs. The part of the signal interfered with is corrected by error detection and correction measures. These error correction measures may include error correction codes, such as block codes or convolution codes.

In OFDM, summation in the time domain of the distributed signals occurs after the distribution of the signals to be transmitted to the sub-carriers, with the amplitudes being added, so that the amplitudes of the superimposed signals assume such a large value at specific instants that the amplifier of the transmitter is driven into its nonlinear range, so that frequency components outside the predefined frequency spectrum may arise. This may occur if the signals distributed to the individual sub-carriers constructively superimpose. Constructive superposition occurs if the phases of the signals are equal.

If a signal, which is transmitted at a specific frequency, is given on a nonlinear characteristic curve, such as, for example, that of an amplifier, frequency components arise at multiples of the specific frequency. If these multiples are outside the transmission frequency spectrum, they are referred to as out-of-band radiation, since the signal energies outside the available spectrum are transmitted and lost for signal transmission because a receiver filters out the out-of-band radiation. In addition, the out-of-band radiation interferes with other transmission systems operating at the frequencies at which the out-of-band radiation occurs.

If new frequency components are present within the transmission frequency spectrum available, undesired signal components are demodulated in the receiver. Crosstalk may therefore occur. The signal quality and therefore the bit error rate of the signal received may be worsened thereby. The bit error rate indicates the number of bits detected incorrectly per bit received. To determine the bit error rate, error detection codes may be used. The OFDM signal is thus like a noise signal on the sub-carriers, after the distribution of the signals to be transmitted, with individually occurring amplitude peaks driving the amplifier of the transmitter into the nonlinear range.

The ratio of amplitude peaks during a signal to the average amplitude of the signal is defined as the crest factor. Therefore, minimizing the crest factor drives the amplifier of the transmitter only in the linear range, thus utilizing it optimally.

A transmitter for transmitting OFDM signals is shown in Figure 1. Data to be transmitted is generated in a data source 1. Data source 1 may be, for example, a microphone. Microphone 1 converts voice signals into electrical signals, and the signals are amplified, coded, and digitized. The digital signals are then transferred as a bit stream to an OFDM modulator 2. The amplification, coding, and digitization are performed by a signal processor, which is connected to microphone 1.

OFDM modulator 2 first performs a differential phase modulation of the signals to be transmitted. For this purpose, differential quadrature phase shift keying (DQPSK) may be used. DQPSK is digital modulation, in which the phase shift of the signal is modulated, for example, the phase shift in a specific time interval, that is, per bit, may be used as a modulation signal or a phase shift of ± 90° may be used. Differential modulation methods do not require an absolute

value to be established in the receiver to demodulate signals, since the information transmitted is contained in the phase shift of the signals transmitted. A bit sequence of 110 thus leads to a phase shift of +90° for each for the two ones and -90° for the zero.

In addition to DQPSK, other differential phase modulation methods and further digital modulation methods may also be used, such as Quadrature Amplitude modulation (QAM), in which both the phase and amplitude are modulated, and other types of phase shift keying (PSK).

DQPSK is a complex modulation method, since the bits of the bit stream, which are fed into OFDM modulator 2, are mapped onto phase changes. If a phase of the signal is changed, a complex plane is used for the graphic representation of the signals as vectors, with a real part being plotted on the abscissa and an imaginary part on the ordinate. A signal having a phase greater than zero is rotated around this phase counterclockwise outward from the abscissa in the complex plane.

According to differential QPSK, OFDM modulator 2 performs the distribution of the signals to be demodulated to the sub-carriers, so that an OFDM signal arises. Since a complex signal arises as a consequence of the DQPSK, which OFDM modulator 2 performs, a first and a second data output from OFDM modulator 2 are connected to a first and second data input of a processor 3, to process two parts of the signal, that is, the imaginary and real parts, separately.

Processor 3 first performs overscanning of the complex signal received from OFDM modulator 2. Experimental values indicate that at least fourfold scanning may be necessary to recognize the amplitude peaks with a high probability. With less scanning, an amplitude peak value may lie between two scanned values.

After overscanning, processor 3 compares the scanned values with a threshold, which is predefined and stored in the transmitter. The threshold determines which amplitudes are too high and therefore which ones would drive the amplifier into the nonlinear range. If a scanned value is greater than the predefined threshold, a difference between the scanned value and the threshold is produced. The correction signal receives the difference as the amplitude for the instant at which the scanned value is greater than the threshold. If the scanned value is equal to or less than the threshold, the correction signal receives an amplitude of zero for the instant.

In a block diagram, Figure 3 shows a cycle that processor 3 performs to establish the correction signal and subtract it from the OFDM signal to be corrected. The scanned values are applied as complex values to input 30 of the block diagram. In block 31, a polar coordinate pair is produced by a table of Cartesian coordinates that describe the complex number of the OFDM signal, so that the amplitude of the OFDM signal may be established. Since the complex OFDM signal includes an imaginary part and a real part, that is, Cartesian coordinates, only the coordinates of the complex number exist in a coordinate system, with the abscissa indicating the real part and the ordinate indicating the imaginary part. However, for a comparison between the threshold and amplitude of the OFDM signal, an absolute value of the complex number is required. The absolute value, however, is the square root of the sum of the individual squares of the coordinate values, that is, of the real part and of the imaginary part, and therefore is the length of a vector from the origin of the coordinate system to the coordinates of the complex number that describes the signal.

In addition, the phase of the OFDM signal is established, since the phase is impressed onto the correction signal for the instant to enhance the quality of the corrected OFDM signal. The conversion from Cartesian coordinates into polar

coordinates provides both the absolute value of the complex OFDM signal and the phase. The phase of the complex OFDM signal is the angle from the abscissa to the vector of the OFDM signal, with measurement being performed counterclockwise. The CORDIC algorithm assigns the Cartesian coordinates to polar coordinates using a table. The amplitude and therefore the absolute value of the complex OFDM signal are compared in block 32 with a predefined threshold. If the absolute value of the complex OFDM signal is below the threshold, the output signal, and therefore the correction signal, is set to zero. If the absolute value of the complex OFDM signal is above the threshold, the difference between the threshold and the absolute value provides the amplitude of the correction signal.

Input signal 30 is multiplied by the output signal of block 32 by a multiplier 33. If the absolute value of the complex OFDM signal is over the threshold, the product is greater than zero, otherwise it is zero. In block 34, Gauss pulses for the real part and for the imaginary part are taken from a memory with the evaluated input signal 30. In subsequent block 35, a complex number and therefore a complex correction signal are produced from the Gauss pulses for the real part and for the imaginary part. Furthermore, the complex correction signal is delayed by a time T2, with time T2 being predefined. The time thus delayed is stored in block 36. Original input signal 30 is delayed in block 37 by predefined time T1 to be stored in memory 38. Times T1 and T2 results in the OFDM signal for which the correction signal is established and the correction signal being stored at the same time in blocks 36 and 37.

A complex subtraction is performed by subtracter 40, so that the OFDM signal is corrected around its amplitude peaks, with the phase of the signal being taken into consideration during the subtraction by retaining the real and imaginary parts for the correction signal. The corrected signal is output signal 39.

Processor 3 performs the correction described above, until no amplitude of the complex OFDM signal is still over the threshold value. Specifically, the correction signal may result in amplitude values that were originally below the threshold being elevated over the threshold by the weighting with the correction signal. Alternatively, the correction algorithm may be performed for a predefined number of repetitions.

In pre-equalizer 4, the corrected complex OFDM signal is pre-equalized according to the characteristic curve of an amplifier 8 of the transmitter by multiplying it by the reciprocal value of the characteristic curve of amplifier 8. After the pre-equalization, the real part and the imaginary part of the signal are each converted into an analog signal by digital-analog converters 5 and 6.

The complex OFDM signal is converted into a real signal and transposed into an intermediate frequency range with a quadrature modulator 7. At the same time, the complex signal, which is mathematically described by $x(t) = a(t) + jb(t)$, is transformed into a real signal and into the intermediate frequency range by $y(t) = a(t)\cos(\omega t) - b(t)\sin(\omega t)$. In this case, ω is a frequency shift into the intermediate frequency range generated by an oscillator connected with quadrature modulator 7.

Amplifier 8 of the transmitter amplifies the signals received from the quadrature modulator, and the amplified signals are transmitted by an antenna 9.

Figure 2 shows a method for reducing the amplitude variance in OFDM signals. Amplitude variance concerns the behavior of OFDM signals, in which the amplitude widely changes, due to the superposition of the signals distributed to the individual sub-carriers.

The data is generated in method step 10. This may occur, for example, as described above. In method step 11, the data generated is modulated using differential phase modulation, with DQPSK being used in this exemplary embodiment. In method step 12, the modulated signals are distributed to the sub-carriers, so that an OFDM signal is created. In method step 13, the OFDM signal is subjected to overscanning, so that a set of scan values are created, which are compared in method step 14 with the threshold for the amplitude. This comparison is examined in method step 23. The procedure continues with method step 15, if an amplitude is over the threshold, and, if no amplitude is over the threshold, the procedure continues with method step 18.

Method step 15 determines the phase of the OFDM signal. In method step 16, the amplitude of a correction signal is formed from the difference of amplitude values that lie over the threshold and impressed onto the associated phase of the OFDM signal. At the instants at which the amplitude values of the OFDM signal lie below the threshold, the amplitude of the correction signal is set to zero. In method step 17, the correction signal is subtracted from the OFDM signal, so that the correction is performed. In method step 18, the corrected signal is pre-equalized according to the inverse characteristic curve of amplifier 8. In method step 19, an analog signal is generated from the digital pre-equalized signal, so that no signal components exist at frequencies which lie outside the transmission frequency spectrum. In method step 19, the quadrature modulation is performed to transpose the analog signal into the transmission frequency domain. In method step 21, the transposed signal is amplified and transmitted in method step 22 by antenna 9.

The correction may be performed in the base band. The baseband is the frequency range in which, for example, voice signals may be present directly after the acoustic electric conversion. However, an exemplary method according to the

present invention may be performed in an intermediate frequency range. For this purpose, a Hilbert transform of the signals should be performed after the scanning and a Hilbert back transform should be performed after the subtraction of the correction signal from the original signal.

For this purpose, a signal, which is already present in an intermediate frequency range and is described by $x(t) = a(t)\cos(\omega t)$, is converted into a complex signal by $y(t) = a(t)\cdot e^{j\omega t}$. The Hilbert back transform, after performing an exemplary method according to the present invention, occurs by formation of the real part of the complex signal.

ABSTRACT OF THE DISCLOSURE

A method of transmitting wireless signals and a transmitter for transmitting wireless signals for optimally operate an amplifier of a transmitter in its linear range, signals being transmitted in orthogonal frequency division multiplexing (OFDM). The amplitudes of the OFDM signals that lie above a predefined threshold are eliminated using an additive correction signal, the phase of the OFDM signals being impressed on the additive correction signal. Furthermore, a correction signal is formed and subtracted from the OFDM signals, until there are no more amplitudes of the OFDM signal above the predefined threshold. Gauss pulses are used as correction signals due to their simple handling. Overscanning of the OFDM signals determines the amplitude values of the OFDM signals.

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Substitute Specification Mark-up copy

[10191/2211]

METHOD OF TRANSMITTING WIRELESS SIGNALS AND TRANSMITTER FOR TRANSMITTING WIRELESS SIGNALS

[Background Information]

FIELD OF THE INVENTION

The present invention relates to a method for transmitting wireless signals and a transmitter for transmitting wireless signals, respectively[, according to the definition of the species of the independent patent claims.].

BACKGROUND INFORMATION

[It is already known, from] M. Lampe and H. Rohling: "Aufwandsgünstige Verfahren zur Reduktion der Außerbandstrahlung in OFDM-Funkübertragungssystemen" [Cost-Effective Method for Reduction of the Out-Of-Band Radiation in OFDM Wireless Transmission Systems], a lecture given at the OFDM technical conference in Braunschweig on 09/03/89, printed in the proceedings of the conference, [that in] refers to a transmitter for transmitting OFDM (orthogonal frequency division multiplexing) signals, in which a reduction of the amplitude variance [is performed to reduce the] reduces out-of-band radiation [due to] caused by the nonlinearity of the transmitter [in that], by subtracting an additive correction signal [is subtracted] from the OFDM signal to be transmitted. [In this case, the] The correction signal is [composed of] the difference between a predefined threshold and the amplitude values of the OFDM signal [which] that lie above [this] the threshold. If the amplitude of the OFDM signal is less than the threshold at a specific instant, then the amplitude of the correction signal at [this] the specific instant is zero.

[Advantages of the Invention] A method for correction of the amplitude variance is discussed in European Published Patent

EL594613286

MARKED UP VERSION OF THE SUBSTITUTE SPECIFICATION

Application No. 735 731, in which generated partial signals are added with different signs, depending on amplitude statistics. In this manner, intervention in the coding is achieved. The additional information should be transmitted to the receiver, where it should be decoded. European Published Patent Application No. 743 768 discusses an envelope of a signal, which comprises many different signals, each modulated with frequency shift keying, being reduced by phase shift of these individual signals.

[The method according to the present invention and the]
SUMMARY OF THE INVENTION
It is believed that an exemplary method and transmitter according to the present invention [having the features of the independent patent claims has the advantage relative to the related art] have an advantage in that the phase of the OFDM signal to be corrected is also impressed onto the correction signal, so that a bit error rate of the OFDM signal and thus the signal quality improve [decisively. In this way, it is possible to modulate, and thus utilize, the]. In this manner, an expensive transmitter for OFDM signals may be modulated and utilized better.

Furthermore, [it is advantageous that,] a less expensive transmitter may be used for a predefined transmitter power, [a less expensive transmitter may be used by using the present invention,] since the amplifier of the transmitter is utilized better.

[Advantageous refinements and improvements of the method for transmitting wireless signals and of the transmitter for transmitting wireless signals are possible through the measures described in the dependent claims.

It is particularly advantageous that the correction signal is] The correction signal may be repeatedly determined and

[repeatedly] subtracted from the already corrected signal. In this [way] manner, the influence of the correction signal on the OFDM signal [is] may be minimized. Through such [an] iteration, other signal components, which are enhanced by the correction signal [are], may be reduced again.

Furthermore, [it is advantageous that] the correction signal [is] may be composed of Gauss pulses. Gauss pulses have the same shape in both the time [range] and [in the] frequency [range] domains, and propagation of a Gauss pulse in the time domain results in []propagation of a Gauss pulse in the frequency domain. In this [way] manner, the handling and composition of the correction signal [is significantly] may be simplified.

In addition, [it is advantageous that] the correction signal [is] may be iteratively determined repeatedly and subtracted from the OFDM signal, until the OFDM signal no longer exceeds a predefined threshold. [By] In this [measure] manner, an iterative method [is obtained which prepares] may prepare the OFDM signal optimally for [the] a given amplifier of the transmitter[, in order] to optimally utilize the dynamics of the amplifier, without out-of-band radiation occurring.

Alternatively, [it is advantageous to preset] according to an exemplary method of the present invention, how long the correction signal is determined and subtracted from the OFDM signal[,] may be preset with experimental values [then entering into this method]. This refinement [simplifies the] may simplify iteration of the correction of the OFDM signal.

Furthermore, [it is advantageous that] overscanning may be performed on the OFDM signal [undergoes overscanning] before the correction is performed. In this [way, it is exactly established which] manner, the amplitudes [occur] occurring in the OFDM signal may be established, since overscanning

provides a more exact resolution of the OFDM signal to be corrected.

[Drawing

Exemplary embodiments of the present invention are shown in the drawing and described more detail in the following description.]

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a transmitter for transmitting OFDM signals[; Figure 2 shows a method].

Figure 2 is a block diagram of the steps of an exemplary method according to the present invention for reducing the amplitude variance in OFDM signals[, and Figure 3 shows a method].

Figure 3 is a block diagram of the steps of an exemplary method according to the present invention for correcting the OFDM signals in a processor.

[Description of the Exemplary Embodiments]

DETAILED DESCRIPTION

Orthogonal frequency division multiplexing (OFDM) is a [known and successful] method used for mobile wireless applications. In OFDM, the signals to be transmitted are distributed to many sub-carriers, these sub-carriers having a specific frequency interval relative to one another, so that the signals distributed to the sub-carriers do not mutually interfere. This behavior is described as orthogonal.

OFDM is therefore used for digital broadcast transmission methods. These include DAB (Digital Audio Broadcasting), DVB (Digital Video Broadcasting), and DRM (Digital Wireless Mondial). These broadcast transmission methods [profit from the property of OFDM that, when a frequency-selective damping

occurs,] benefit from OFDM because only a small part of the broadcast signal transmitted is interfered with when a frequency-selective damping occurs, since the broadcast signal [was] is distributed [to] in multiple frequencies, and only one part of the signal [was] is interfered with, which [was] is transmitted on a frequency at which a strong damping [occurred] occurs. The part of the signal interfered with is corrected by error detection and correction measures. These error correction measures may include error correction codes, such as block codes or convolution codes.

In OFDM, summation in the time domain of the distributed signals occurs after the distribution of the signals to be transmitted to the sub-carriers, with the amplitudes [able to be] being added [in such a way], so that the amplitudes of the superimposed signals assume such a large value at specific instants that the amplifier of the transmitter is driven into its nonlinear range, so that frequency components outside the predefined frequency spectrum may arise. [Such a case occurs] This may occur if the signals distributed to the individual sub-carriers constructively superimpose. Constructive superposition occurs if the phases of the signals are equal.

If a signal, which is transmitted at a specific frequency, is given on a nonlinear characteristic curve, [e.g.] such as, for example, that of an amplifier, frequency components arise at multiples of the specific frequency. If these multiples are outside the transmission frequency spectrum, they are referred to as out-of-band radiation, since [then] the signal energies outside the available spectrum are transmitted and [are thus] lost for signal transmission[,] because a receiver filters out the out-of-band radiation. In addition, the out-of-band radiation interferes with other transmission systems [which are used] operating at the frequencies at which the out-of-band radiation occurs.

If new frequency components are present within the transmission frequency spectrum available, undesired signal components are demodulated in the receiver. Crosstalk may therefore [occurs] occur. The signal quality and therefore the bit error rate of the signal received [are decisively] may be worsened thereby. The bit error rate indicates [how many] the number of bits [are] detected incorrectly per bit received. [In order to] To determine the bit error rate, [the] error detection codes [are] may be used. The OFDM signal is thus [present] like a noise signal on the sub-carriers, after the distribution of the signals to be transmitted, with individually occurring amplitude peaks driving the amplifier of the transmitter into the nonlinear range.

The ratio of amplitude peaks during a signal to the average amplitude of the signal is defined as the crest factor. Therefore, minimizing [this] the crest factor [is used for driving] drives the amplifier of the transmitter only in the linear range [and], thus utilizing it optimally.

A transmitter for transmitting OFDM signals is [illustrated] shown in Figure 1. [The data] Data to be transmitted is generated in a data source 1. [In this case, data] Data source 1 [is] may be, for example, a microphone. Microphone 1 converts voice signals into electrical signals, and the signals are amplified, coded, and digitized. The digital signals are then transferred as a bit stream to an OFDM modulator 2. The amplification, coding, and digitization are performed by a signal processor, which is connected to microphone 1.

OFDM modulator 2 first performs a differential phase modulation of the signals to be transmitted. For this purpose, differential quadrature phase shift keying (DQPSK) [is] may be used. DQPSK is digital modulation, in which the phase shift of the signal is modulated[. In this case,], for example, the

phase shift in a specific time interval, [i.e.] that is, per bit, [is] may be used as a modulation signal[. A] or a phase shift of ± 90° [is] may be used [here]. Differential modulation methods [have the advantage that no] do not require an absolute value [must] to be established in the receiver to demodulate signals, since the information transmitted is contained in the phase shift of the signals transmitted. A bit sequence of 110 thus leads to a phase shift of +90° for each for the two ones and -90° for the zero.

In addition to DQPSK, other differential phase modulation methods and further digital modulation methods may also be used[.], such as Quadrature [amplitude] Amplitude modulation (QAM), in which both the phase and amplitude are modulated, and [all] other types of phase shift keying (PSK) [are of particular importance here].

DQPSK is a complex modulation method, since the bits of the bit stream, which are fed into OFDM modulator 2, are mapped onto phase changes. If a phase of the signal is changed, a complex plane is used [as] for the graphic representation of the signals as vectors, with a real part being plotted on the abscissa and an imaginary part on the ordinate. A signal having a phase greater than zero is rotated around this phase counterclockwise outward from the abscissa in the complex plane.

According to differential QPSK, OFDM modulator 2 performs the distribution of the signals to be demodulated to the sub-carriers, so that an OFDM signal arises. Since a complex signal arises as a consequence of the DQPSK, which OFDM modulator 2 performs, a first and a second data output from OFDM modulator 2 are connected to a first and second data input of a processor 3, [in order] to process two parts of the signal, that is, the imaginary and real parts, separately.

Processor 3 first performs overscanning of the complex signal [coming] received from OFDM modulator 2. Experimental values [have shown] indicate that at least fourfold scanning [is] may be necessary to recognize the amplitude peaks with a high probability. With less scanning, [it may happen that] an amplitude peak value [lies exactly] may lie between two scanned values.

After [the] overscanning, processor 3 compares the scanned values with a threshold, which is predefined and stored in the transmitter. The threshold determines which amplitudes are too high and therefore which ones would drive the amplifier into the nonlinear range. If a scanned value is greater than the predefined threshold, a difference between [this] the scanned value and the threshold is produced. The correction signal receives [this] the difference as the amplitude for the instant at which the scanned value [was] is greater than the threshold. If the scanned value is equal to or less than the threshold, the correction signal receives an amplitude of zero for [this] the instant.

In a block diagram, Figure 3 [explains the] shows a cycle [which] that processor 3 [passes through in order] performs to establish the correction signal and subtract it from the OFDM signal to be corrected. The scanned values are applied as complex values to input 30 of the block diagram. In block 31, a polar coordinate pair is produced by [means of] a table of Cartesian coordinates [which] that describe the complex number of the OFDM signal[. This is necessary], so that the amplitude of the OFDM signal may be established. Since the complex OFDM signal [then exists as] includes an imaginary part and a real part, [i.e., as] that is, Cartesian coordinates, only the coordinates of the complex number exist in a coordinate system, with the abscissa indicating the real part and the ordinate indicating the imaginary part. However, [to achieve] for a comparison between the threshold and amplitude of the

OFDM signal, an absolute value of the complex number is [necessary. This] required. The absolute value, however, is the square root of the sum of the individual squares of the coordinate values, [i.e.] that is, of the real part and of the imaginary part, and therefore is the length of a vector from the origin of the coordinate system to the coordinates of the complex number [which] that describes the signal.

In addition, the phase of the OFDM signal is established, since [this] the phase is [to be] impressed onto the correction signal for [this] the instant to enhance the quality of the corrected OFDM signal. The conversion from Cartesian coordinates into polar coordinates provides both the absolute value of the complex OFDM signal and the phase. The phase of the complex OFDM signal is the angle from the abscissa to the vector of the OFDM signal, with measurement being performed counterclockwise. The CORDIC algorithm [is used for this assignment of] assigns the Cartesian coordinates to polar coordinates [by means of] using a table. The amplitude and therefore the absolute value of the complex OFDM signal are compared in block 32 with a predefined threshold. If the absolute value of the complex OFDM signal is below the threshold, the output signal, and therefore the correction signal, is set to zero. If the absolute value of the complex OFDM signal is above the threshold, the difference between the threshold and the absolute value provides the amplitude of the correction signal.

Input signal 30 is multiplied by the output signal of block 32 by [means of] a multiplier 33. If the absolute value of the complex OFDM signal [was] is over the threshold, the product is [then] greater than zero, otherwise it is zero. In block 34, Gauss pulses for the real part and for the imaginary part are taken from a memory with the evaluated input signal 30. In subsequent block 35, a complex number and therefore a complex correction signal are produced from the Gauss pulses for the

real part and for the imaginary part. Furthermore, the complex correction signal is delayed by a time T2, with time T2 being predefined. The time thus delayed is stored in block 36. Original input signal 30 is delayed in block 37 by predefined time T1 [in order] to [then] be stored in memory 38. Times T1 and T2 [are such that] results in the OFDM signal for which the correction signal is established and the correction signal [are] being stored at the same time in blocks 36 and 37.

A complex subtraction is performed by subtracter 40, so that the OFDM signal is corrected around its amplitude peaks, with the phase of the signal being taken into consideration during the subtraction by retaining the real and imaginary parts for the correction signal. The corrected signal [exists as] is output signal 39.

Processor 3 performs the correction [just] described above, until no amplitude of the complex OFDM signal is still over the threshold value. Specifically, the correction signal may result in amplitude values [which] that were originally below the threshold being elevated over the threshold by the weighting with the correction signal. Alternatively, the correction algorithm may be performed for a predefined number of repetitions.

In pre-equalizer 4, the corrected complex OFDM signal is pre-equalized according to the characteristic curve of an amplifier 8 of the transmitter [in that] by multiplying it [is multiplied] by the reciprocal value of the characteristic curve of amplifier 8. After the pre-equalization, the real part and the imaginary part of the signal are each converted into an analog signal by [means of] digital-analog converters 5 and 6.

The complex OFDM signal is converted into a real signal and transposed into an intermediate frequency range with a

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quadrature modulator 7. At the same time, the complex signal, which is mathematically described [with] by $x(t) = a(t) + jb(t)$, is transformed into a real signal and into the intermediate frequency range by [the following specification:] $y(t) = a(t)\cos(\omega t) - b(t)\sin(\omega t)$. In this case, ω is a frequency shift into the intermediate frequency range[, with ω being] generated by an oscillator connected with quadrature modulator 7.

Amplifier 8 of the transmitter amplifies the signals [coming] received from the quadrature modulator, and the amplified signals are transmitted by [means of] an antenna 9.

Figure 2 shows a method for reducing the amplitude variance in OFDM signals. Amplitude variance [refers to] concerns the behavior of OFDM signals, [where] in which the amplitude [has] widely [changing amplitudes] changes, due to the superposition of the signals distributed to the individual sub-carriers.

The data is generated in method step 10. This [occurs] may occur, for example, as described above. In method step 11, the data generated is modulated using differential phase modulation, with DQPSK being used [here] in this exemplary embodiment. In method step 12, the modulated signals are distributed to the sub-carriers, so that an OFDM signal [arises] is created. In method step 13, the OFDM signal is subjected to overscanning, so that a set of scan values [exists] are created, which are compared in method step 14 with the threshold for the amplitude. This comparison is examined in method step 23. The procedure continues with method step 15, if an amplitude is over the threshold, and, if no amplitude is over the threshold [anymore,], the procedure continues with method step 18.

[In method] Method step 15[,] determines the phase of the OFDM signal [is determined]. In method step 16, the amplitude of a

correction signal is formed from the difference of amplitude values [which] that lie over the threshold and impressed onto the associated phase of the OFDM signal. At the instants at which the amplitude values of the OFDM signal lie below the threshold, the amplitude of the correction signal is set to zero. In method step 17, the correction signal is subtracted from the OFDM signal, so that the correction is performed. In method step 18, the corrected signal is pre-equalized according to the inverse characteristic curve of amplifier 8. In method step 19, an analog signal is generated from the digital pre-equalized signal, so that no signal components exist at frequencies which lie outside the transmission frequency spectrum. In method step 19, the quadrature modulation is performed to transpose the analog signal into the transmission frequency domain. In method step 21, the transposed signal is amplified and transmitted in method step 22 by antenna 9.

[In this case, the] The correction [was] may be performed in the base band. [This] The baseband is the frequency range in which, for example, [the] voice signals [are] may be present directly after the acoustic electric conversion. However, [it is also possible to perform the] an exemplary method according to the present invention may be performed in an intermediate frequency range. For this purpose, [it is necessary that] a Hilbert transform of the signals [is] should be performed after the scanning and a Hilbert back transform [is] should be performed after the subtraction of the correction signal from the original signal.

For this purpose, a signal, which is already present in an intermediate frequency range and is described [with] by $x(t) = a(t)\cos(\omega t)$, is converted into a complex signal [which is then described with] by $y(t) = a(t)\cdot e^{j\omega t}$. The Hilbert back transform, after performing [the] an exemplary method

according to the present invention, occurs [simply] by formation of the real part of the complex signal.

[Abstract]

ABSTRACT OF THE DISCLOSURE

A method of transmitting wireless signals and a transmitter for transmitting wireless signals [are proposed, respectively, which are used to] for optimally operate an amplifier of [the] a transmitter [(8)] in its linear range, signals being transmitted in orthogonal frequency division multiplexing (OFDM). The amplitudes of the OFDM signals that lie above a predefined threshold are eliminated using an additive correction signal, the phase of the OFDM signals being impressed on the additive correction signal. Furthermore, a correction signal is formed and subtracted from the OFDM signals, until there are no more amplitudes of the OFDM signal above the predefined threshold. Gauss pulses are used as correction signals due to their simple handling. Overscanning of the OFDM signals [is used to determine] determines the amplitude values of the OFDM signals.

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METHOD OF TRANSMITTING WIRELESS SIGNALS AND TRANSMITTER FOR TRANSMITTING WIRELESS SIGNALS

Background Information

The present invention relates to a method for transmitting wireless signals and a transmitter for transmitting wireless signals, respectively, according to the definition of the species of the independent patent claims.

It is already known, from M. Lampe and H. Rohling: "Aufwandsgünstige Verfahren zur Reduktion der Außerbandstrahlung in OFDM-Funkübertragungssystemen" [Cost-Effective Method for Reduction of the Out-Of-Band Radiation in OFDM Wireless Transmission Systems], a lecture given at the OFDM technical conference in Braúnschweig on 09/03/89, printed in the proceedings of the conference, that in a transmitter for transmitting OFDM (orthogonal frequency division multiplexing) signals, a reduction of the amplitude variance is performed to reduce the out-of-band radiation due to the nonlinearity of the transmitter in that an additive correction signal is subtracted from the OFDM signal to be transmitted. In this case, the correction signal is composed of the difference between a predefined threshold and the amplitude values of the OFDM signal which lie above this threshold. If the amplitude of the OFDM signal is less than the threshold at a specific instant, then the amplitude of the correction signal at this specific instant is zero.

Advantages of the Invention

The method according to the present invention and the transmitter according to the present invention having the features of the independent patent claims has the advantage relative to the related art that the phase of the OFDM signal to be corrected is also impressed onto the correction signal,

so that a bit error rate of the OFDM signal and thus the signal quality improve decisively. In this way, it is possible to modulate, and thus utilize, the expensive transmitter for OFDM signals better.

Furthermore, it is advantageous that, for a predefined transmitter power, a less expensive transmitter may be used by using the present invention, since the amplifier of the transmitter is utilized better.

Advantageous refinements and improvements of the method for transmitting wireless signals and of the transmitter for transmitting wireless signals are possible through the measures described in the dependent claims.

It is particularly advantageous that the correction signal is repeatedly determined and repeatedly subtracted from the already corrected signal. In this way, the influence of the correction signal on the OFDM signal is minimized. Through such an iteration, other signal components which are enhanced by the correction signal are reduced again.

Furthermore, it is advantageous that the correction signal is composed of Gauss pulses. Gauss pulses have the same shape in the time range and in the frequency range and propagation of a Gauss pulse in the time domain results in

propagation of a Gauss pulse in the frequency domain. In this way, the handling and composition of the correction signal is significantly simplified.

In addition, it is advantageous that the correction signal is iteratively determined repeatedly and subtracted from the OFDM signal until the OFDM signal no longer exceeds a predefined threshold. By this measure, an iterative method is obtained which prepares the OFDM signal optimally for the given amplifier of the transmitter, in order to optimally utilize the dynamics of the amplifier without out-of-band radiation occurring.

Alternatively, it is advantageous to preset how long the correction signal is determined and subtracted from the OFDM signal, with experimental values then entering into this method. This refinement simplifies the iteration of the correction of the OFDM signal.

Furthermore, it is advantageous that the OFDM signal undergoes overscanning before the correction is performed. In this way, it is exactly established which amplitudes occur in the OFDM signal, since overscanning provides a more exact resolution of the OFDM signal to be corrected.

Drawing

Exemplary embodiments of the present invention are shown in the drawing and described more detail in the following description. Figure 1 shows a transmitter for transmitting OFDM signals; Figure 2 shows a method for reducing the amplitude variance in OFDM signals, and Figure 3 shows a method for correcting the OFDM signals in a processor.

Description of the Exemplary Embodiments

Orthogonal frequency division multiplexing (OFDM) is a known and successful method for mobile wireless applications. In OFDM, the signals to be transmitted are distributed to many sub-carriers, these sub-carriers having a specific frequency interval relative to one another so that the signals distributed to the sub-carriers do not mutually interfere. This behavior is described as orthogonal.

OFDM is therefore used for digital broadcast transmission methods. These include DAB (Digital Audio Broadcasting), DVB (Digital Video Broadcasting), and DRM (Digital Wireless Mondial). These broadcast transmission methods profit from the property of OFDM that, when a frequency-selective damping occurs, only a small part of the broadcast signal transmitted is interfered with, since the broadcast signal was distributed to multiple frequencies and only one part of the signal was interfered with, which was transmitted on a frequency at which a strong damping occurred. The part of the signal interfered with is corrected by error detection and correction measures. These error correction measures include error correction codes such as block codes or convolution codes.

In OFDM, summation in the time domain of the distributed signals occurs after the distribution of the signals to be transmitted to the sub-carriers, with the amplitudes able to be added in such a way that the amplitudes of the superimposed signals assume such a large value at specific instants that the amplifier of the transmitter is driven into its nonlinear range, so that frequency components outside the predefined frequency spectrum may arise. Such a case occurs if the signals distributed to the individual sub-carriers constructively superimpose. Constructive superposition occurs if the phases of the signals are equal.

If a signal which is transmitted at a specific frequency is given on a nonlinear characteristic curve, e.g., that of an amplifier, frequency components arise at multiples of the

specific frequency. If these multiples are outside the transmission frequency spectrum, they are referred to as out-of-band radiation, since then signal energies outside the available spectrum are transmitted and are thus lost for signal transmission, because a receiver filters out the out-of-band radiation. In addition, the out-of-band radiation interferes with other transmission systems which are used at the frequencies at which the out-of-band radiation occurs.

If new frequency components are present within the transmission frequency spectrum available, undesired signal components are demodulated in the receiver. Crosstalk therefore occurs. The signal quality and therefore the bit error rate of the signal received are decisively worsened thereby. The bit error rate indicates how many bits are detected incorrectly per bit received. In order to determine the bit error rate, the error detection codes are used. The OFDM signal is thus present like a noise signal on the sub-carriers after the distribution of the signals to be transmitted, with individually occurring amplitude peaks driving the amplifier of the transmitter into the nonlinear range.

The ratio of amplitude peaks during a signal to the average amplitude of the signal is defined as the crest factor. Therefore, minimizing this crest factor is used for driving the amplifier of the transmitter only in the linear range and thus utilizing it optimally.

A transmitter for transmitting OFDM signals is illustrated in Figure 1. The data to be transmitted is generated in a data source 1. In this case, data source 1 is a microphone. Microphone 1 converts voice signals into electrical signals, and the signals are amplified, coded, and digitized. The digital signals are then transferred as a bit stream to an OFDM modulator 2. The amplification, coding, and digitization

are performed by a signal processor which is connected to microphone 1.

OFDM modulator 2 first performs a differential phase modulation of the signals to be transmitted. For this purpose, differential quadrature phase shift keying (DQPSK) is used. DQPSK is digital modulation in which the phase shift of the signal is modulated. In this case, the phase shift in a specific time interval, i.e., per bit, is used as a modulation signal. A phase shift of ± 90° is used here. Differential modulation methods have the advantage that no absolute value must be established in the receiver to demodulate signals, since the information transmitted is contained in the phase shift of the signals transmitted. A bit sequence of 110 thus leads to a phase shift of +90° each for the two ones and -90° for the zero.

In addition to DQPSK, other differential phase modulation methods and further digital modulation methods may also be used. Quadrature amplitude modulation (QAM), in which both the phase and amplitude are modulated, and all types of phase shift keying (PSK) are of particular importance here.

DQPSK is a complex modulation method, since the bits of the bit stream which are fed into OFDM modulator 2 are mapped onto phase changes. If a phase of the signal is changed, a complex plane is used as for the graphic representation of the signals as vectors, with a real part being plotted on the abscissa and an imaginary part on the ordinate. A signal having a phase greater than zero is rotated around this phase counterclockwise outward from the abscissa in the complex plane.

According to differential QPSK, OFDM modulator 2 performs the distribution of the signals to be demodulated to the sub-carriers so that an OFDM signal arises. Since a complex signal arises as a consequence of the DQPSK which OFDM modulator 2

performs, a first and a second data output from OFDM modulator 2 are connected to a first and second data input of a processor 3, in order to process two parts of the signal, imaginary and real parts, separately.

Processor 3 first performs overscanning of the complex signal coming from OFDM modulator 2. Experimental values have shown that at least fourfold scanning is necessary to recognize the amplitude peaks with high probability. With less scanning, it may happen that an amplitude peak value lies exactly between two scanned values.

After the overscanning, processor 3 compares the scanned values with a threshold which is predefined and stored in the transmitter. The threshold determines which amplitudes are too high and therefore would drive the amplifier into the nonlinear range. If a scanned value is greater than the predefined threshold, a difference between this scanned value and the threshold is produced. The correction signal receives this difference as the amplitude for the instant at which the scanned value was greater than the threshold. If the scanned value is equal to or less than the threshold, the correction signal receives an amplitude of zero for this instant.

In a block diagram, Figure 3 explains the cycle which processor 3 passes through in order to establish the correction signal and subtract it from the OFDM signal to be corrected. The scanned values are applied as complex values to input 30 of the block diagram. In block 31, a polar coordinate pair is produced by means of a table of Cartesian coordinates which describe the complex number of the OFDM signal. This is necessary so that the amplitude of the OFDM signal may be established. Since the complex OFDM signal then exists as an imaginary part and a real part, i.e., as Cartesian coordinates, only the coordinates of the complex number exist in a coordinate system, with the abscissa indicating the real part and the ordinate the imaginary part. However, to achieve

a comparison between the threshold and amplitude of the OFDM signal, an absolute value of the complex number is necessary. This absolute value, however, is the square root of the sum of the individual squares of the coordinate values, i.e., of the real part and of the imaginary part, and therefore is the length of a vector from the origin of the coordinate system to the coordinates of the complex number which describes the signal.

In addition, the phase of the OFDM signal is established since this phase is to be impressed onto the correction signal for this instant to enhance the quality of the corrected OFDM signal. The conversion from Cartesian coordinates into polar coordinates provides both the absolute value of the complex OFDM signal and the phase. The phase of the complex OFDM signal is the angle from the abscissa to the vector of the OFDM signal, with measurement being performed counterclockwise. The CORDIC algorithm is used for this assignment of Cartesian coordinates to polar coordinates by means of a table. The amplitude and therefore the absolute value of the complex OFDM signal are compared in block 32 with a predefined threshold. If the absolute value of the complex OFDM signal is below the threshold, the output signal, and therefore the correction signal, is set to zero. If the absolute value of the complex OFDM signal is above the threshold, the difference between the threshold and the absolute value provides the amplitude of the correction signal.

Input signal 30 is multiplied by the output signal of block 32 by means of a multiplier 33. If the absolute value of the complex OFDM signal was over the threshold, the product is then greater than zero, otherwise it is zero. In block 34, Gauss pulses for the real part and for the imaginary part are taken from a memory with the evaluated input signal 30. In subsequent block 35, a complex number and therefore a complex correction signal are produced from the Gauss pulses for the

real part and for the imaginary part. Furthermore, the complex correction signal is delayed by a time T2, with time T2 being predefined. The time thus delayed is stored in block 36. Original input signal 30 is delayed in block 37 by predefined time T1 in order to then be stored in memory 38. Times T1 and T2 are such that the OFDM signal for which the correction signal is established and the correction signal are stored at the same time in blocks 36 and 37.

A complex subtraction is performed by subtracter 40, so that the OFDM signal is corrected around its amplitude peaks, with the phase of the signal being taken into consideration during the subtraction by retaining the real and imaginary parts for the correction signal. The corrected signal exists as output signal 39.

Processor 3 performs the correction just described until no amplitude of the complex OFDM signal is still over the threshold value. Specifically, the correction signal may result in amplitude values which were originally below the threshold being elevated over the threshold by the weighting with the correction signal. Alternatively, the correction algorithm may be performed for a predefined number of repetitions.

In pre-equalizer 4, the corrected complex OFDM signal is pre-equalized according to the characteristic curve of an amplifier 8 of the transmitter in that it is multiplied by the reciprocal value of the characteristic curve of amplifier 8. After the pre-equalization, the real part and the imaginary part of the signal are each converted into an analog signal by means of digital-analog converters 5 and 6.

The complex OFDM signal is converted into a real signal and transposed into an intermediate frequency range with a quadrature modulator 7. At the same time, the complex signal, which is mathematically described with $x(t) = a(t) + jb(t)$, is

transformed into a real signal and into the intermediate frequency range by the following specification: $y(t) = a(t)\cos(\omega t) - b(t)\sin(\omega t)$. In this case, ω is a frequency shift into the intermediate frequency range, with ω being generated by an oscillator connected with quadrature modulator 7.

Amplifier 8 of the transmitter amplifies the signals coming from the quadrature modulator and the amplified signals are transmitted by means of an antenna 9.

Figure 2 shows a method for reducing the amplitude variance in OFDM signals. Amplitude variance refers to the behavior of OFDM signals, where the amplitude has widely changing amplitudes due to the superposition of the signals distributed to the individual sub-carriers.

The data is generated in method step 10. This occurs, for example, as described above. In method step 11, the data generated is modulated using differential phase modulation, with DQPSK being used here. In method step 12, the modulated signals are distributed to the sub-carriers, so that an OFDM signal arises. In method step 13, the OFDM signal is subjected to overscanning, so that a set of scan values exists which are compared in method step 14 with the threshold for the amplitude. This comparison is examined in method step 23. The procedure continues with method step 15 if an amplitude is over the threshold, and, if no amplitude is over the threshold anymore, with method step 18.

In method step 15, the phase of the OFDM signal is determined. In method step 16, the amplitude of a correction signal is formed from the difference of amplitude values which lie over the threshold and impressed onto the associated phase of the OFDM signal. At the instants at which the amplitude values of the OFDM signal lie below the threshold, the amplitude of the correction signal is set to zero. In method step 17, the

correction signal is subtracted from the OFDM signal, so that the correction is performed. In method step 18, the corrected signal is pre-equalized according to the inverse characteristic curve of amplifier 8. In method step 19, an analog signal is generated from the digital pre-equalized signal, so that no signal components exist at frequencies which lie outside the transmission frequency spectrum. In method step 19, the quadrature modulation is performed to transpose the analog signal into the transmission frequency domain. In method step 21, the transposed signal is amplified and transmitted in method step 22 by antenna 9.

In this case, the correction was performed in the base band. This is the frequency range in which, for example, the voice signals are present directly after the acoustic electric conversion. However, it is also possible to perform the method according to the present invention in an intermediate frequency range. For this purpose, it is necessary that a Hilbert transform of the signals is performed after the scanning and a Hilbert back transform is performed after the subtraction of the correction signal from the original signal.

For this purpose, a signal which is already present in an intermediate frequency range and is described with $x(t) = a(t)\cos(\omega t)$ is converted into a complex signal which is then described with $y(t) = a(t) \cdot e^{j\omega t}$. The Hilbert back transform after performing the method according to the present invention occurs simply by formation of the real part of the complex signal.

What is claimed is:

1. A method of transmitting wireless signals, the wireless signals being distributed to various sub-carriers, the wireless signals being modulated using differential phase modulation, the wireless signals being scanned after modulation in order to generate scanned values of the modulated wireless signal, amplitude values of the wireless signals being determined by means of the scanned values, the amplitude values being compared to a predefined threshold in order to obtain a difference, the difference being subtracted from the wireless signals before transmission as a correction signal in order to reduce the amplitude values of the wireless signals that are above the predefined threshold to a value of the threshold, the corrected wireless signals being pre-equalized, the pre-equalized wireless signals being converted to analog wireless signals by means of digital-analog converters (5, 6), the analog wireless signals being amplified and transmitted, wherein a phase of the wireless signals is determined and the correction signal is provided with the phase of the wireless signals before the correction signal is subtracted from the wireless signals.

2. The method according to Claim 1, wherein a correction signal is repeatedly subtracted from the wireless signals, the correction signal being determined again for each correction.

3. The method according to Claim 2, wherein Gauss pulses are used as correction signals.

4. The method according to Claim 2, wherein the correction signal is subtracted from the wireless signals until the amplitudes of the corrected wireless signals are at most equal to the predefined threshold.

5. The method according to Claim 2, wherein it is predefined how often the correction signal is to be subtracted from the wireless signals.

6. The method according to the Claims 4 or 5, wherein the wireless signals are overscanned.

7. A transmitter for transmitting wireless signals, a modulator (2) distributing digital signals to be transmitted to various sub-carriers and performing a differential phase modulation on the digital signals, a processor (3) scanning the digital signals distributed to various sub-carriers, the processor (3) establishing amplitudes of the scanned signals, the processor (3) comparing the amplitudes to a predefined threshold and forming a difference between the amplitudes and the threshold for the amplitudes which lie above the threshold, the processor (3) forming a correction signal using the difference as the amplitude of the correction signal, the processor (3) subtracting the correction signal from the digital signals distributed to various sub-carriers, a pre-equalizer (4) pre-equalizing the corrected digital signals, digital/analog converters (5,6) converting the digital signals distributed to various sub-carriers into analog signals, wherein the processor (3) determines a phase of the scanned signals, and the processor (3) provides the correction signal with the phase before the processor (3) subtracts the correction signal from the scanned signal.

8. The transmitter according to Claim 7, wherein the processor (3) repeatedly subtracts the correction signal from the wireless signals, the processor (3) determining the correction signal again for each correction.

9. The transmitter according to Claim 8, wherein the processor (3) subtracts the correction signal until the amplitude values of the wireless signals are at most equal to the predefined threshold.

10. The transmitter according to Claim 8, wherein the processor (3) subtracts the correction signal from the wireless signals for as long as a predefined value designates.

11. The transmitter according to Claim 9 or 10, wherein the processor (3) generates Gauss pulses as the correction signal.

12. The transmitter according to Claim 11, wherein the processor (3) performs overscanning on the signals distributed to sub-carriers.

Abstract

A method of transmitting wireless signals and a transmitter for transmitting wireless signals are proposed, respectively, which are used to optimally operate an amplifier of the transmitter (8) in its linear range, signals being transmitted in orthogonal frequency division multiplexing (OFDM). The amplitudes of the OFDM signals that lie above a predefined threshold are eliminated using an additive correction signal, the phase of the OFDM signals being impressed on the additive correction signal. Furthermore, a correction signal is formed and subtracted from the OFDM signals until there are no more amplitudes of the OFDM signal above the predefined threshold. Gauss pulses are used as correction signals due to their simple handling. Overscanning of the OFDM signals is used to determine the amplitude values of the OFDM signals.

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Fig. 1

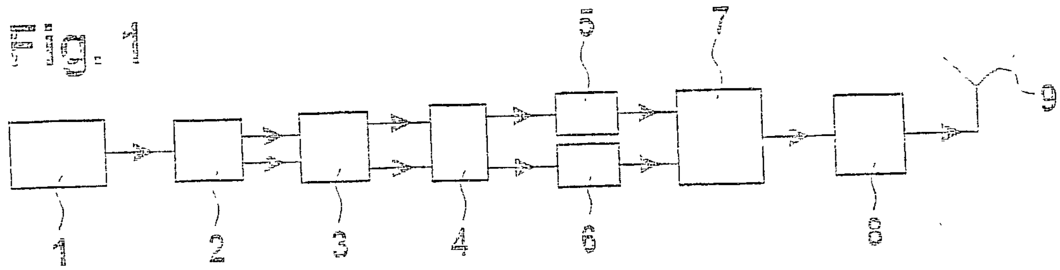


Fig. 2

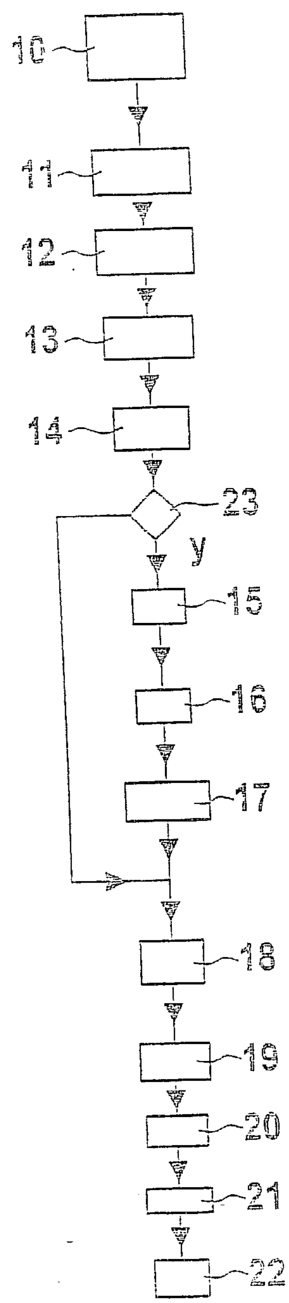
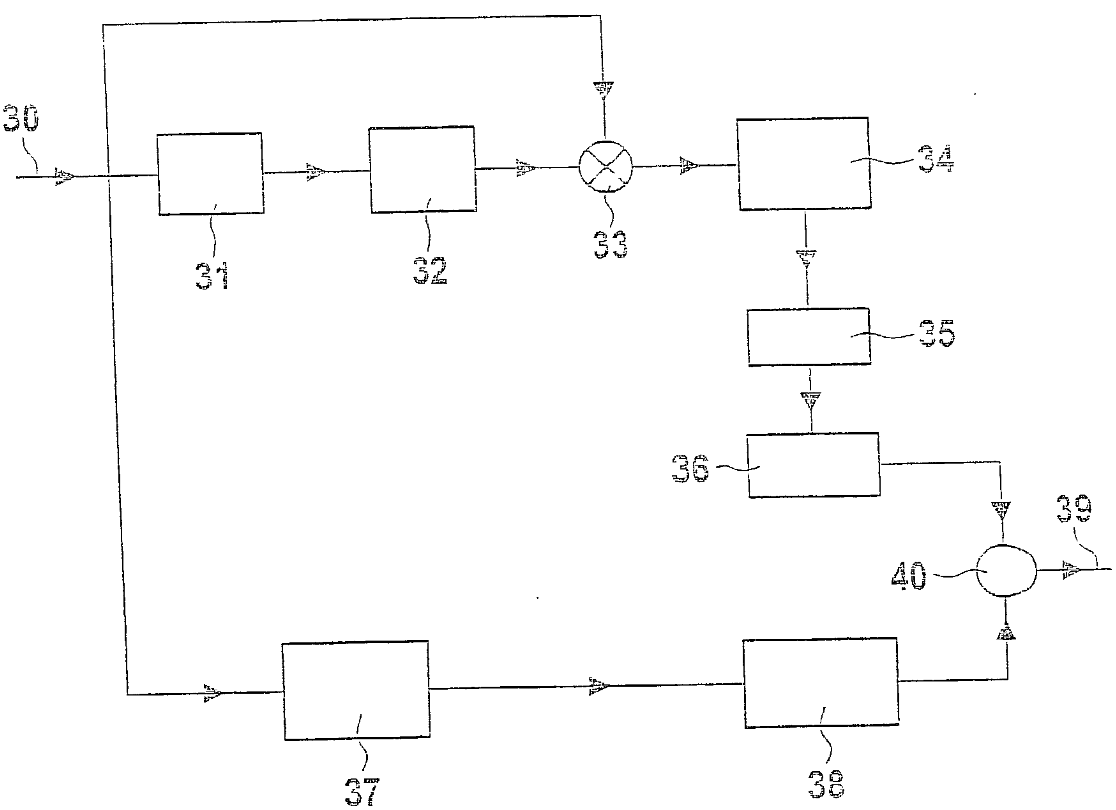


Fig. 3



[10191/2211]

DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled **METHOD OF TRANSMITTING WIRELESS SIGNALS AND TRANSMITTER FOR TRANSMITTING WIRELESS SIGNALS**, the specification of which was filed as International Application **PCT/DE00/03020** on September 2, 2000;

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, § 1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application(s) for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

EL039820681
~~EL594613286~~

PRIOR FOREIGN APPLICATION(S)

Number	Country filed	Day/month/year	Priority Claimed Under 35 USC 119
199 44 558.3	Fed. Rep. of Germany	17 September 1999	Yes

And I hereby appoint Richard L. Mayer (Reg. No. 22,490) and Gerard A. Messina (Reg. No. 35,952) my attorneys with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith.

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful and false statements may jeopardize the validity of the application or any patent issued thereon.

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